Shallow geothermal energy: Geological energy for the ecological transition and its inclusion in European and national energy policies

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Of all possible forms of energy substitution of oil and gas, geothermal energy is the one most closely related to geology. Shallow geothermal energy is a source of clean, renewable and virtually inexhaustible energy that is directly related to geographical areas, where heat fluxes and temperature gradients can vary due to several factors. This document summarises the current situation of the policies on the use of shallow (low temperature) geothermal energy in Europe to generate hot water and air conditioning. The current status of legislation in some European countries and the promotion of shallow geothermal energy in the EU28 are also discussed.

Parmi toutes les formes d'énergie de remplacement du pétrole et du gaz, l'énergie géothermique représente celle qui est la plus proche de la géologie. L'énergie géothermique à faible profondeur constitue une source d'énergie propre, renouvelable et virtuellement éternelle, en relation directe avec les zones géologiques pour lesquelles les gradients de flux et de température peuvent varier en fonction de plusieurs facteurs. Le document présenté résume la situation actuelle concernant les politiques européennes d'utilisation de la géothermie peu profonde (basse température ou basse enthalpie) pour la production d'eau chaude et d'air conditionné. Sont abordés ici l'état actuel de la législation relative à quelques pays européens ainsi que la promotion de l'énergie basse enthalpie à destination des 28 pays de l'Union Européenne.

De todas las fuentes de energía posibles para sustituir al Oil&Gas, la energía geotérmica es la que más estrechamente se relaciona con la geología. La energía geotérmica superficial es una fuente de energía limpia, renovable y virtualmente inextinguible que está directamente relacionada con determinadas áreas geográficas, donde el flujo de calor y el gradiente de temperatura puede variar debido a determinados factores. Este documento resume la actual situación de las políticas de uso de la energía geotérmica de baja entalpia en Europa para generar agua caliente y aire acondicionado. De la misma manera, se ponen en discusión el estado actual de la legislación y la promoción de esta energía en algunos de los países europeos.

Introduction

In Europe, the air conditioning (heating and cooling) of buildings makes up a large part of the energetic demand in the present society, since heat/cold is a vital part of the energetic needs of the human beings. This type of energy demand accounts for approximately 86% of final energy consumption in homes, 76% in commerce, services and agriculture and 55% in the manufacturing industry (Burkhard, 2011).

At present, 81% of this energy required for air conditioning in the EU28 countries is generated from coal and oil. This is why the current heating and cooling systems not only increase the high cost of imports of fossil fuels from third countries (some of them unfriendly to international environmental regulations), but also represent an important contribution to greenhouse gas emissions and, by extension, to climate change. In this context, shallow geothermal energy for space heating/cooling and hot water represents a source of renewable energy with a large potential for energy savings and also reduction of pollution, since it is used in the same place where it is produced.

A definition of what shallow geothermal energy is found in Article 2(c) of Directive 2009/28/EC: 'Shallow geothermal energy means energy stored in the form of heat under the surface of solid earth'. Similarly, UNECE (the United Nations Economic Commission for Europe), defines geothermal energy as the thermal energy contained in a body of rock, sediment and/or soil, including any fluid contained in them that is available for extraction and conversion into energy products.

Among the different types of geothermal energy is the shallow type, also known as low or very low enthalpy (since the temperatures in the shallow soil located up to 500 m of depth are low), which can achieve

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up to 70% energy savings compared to traditional systems of air conditioning and hot water generation (Stylianou *et al.*, 2017) and is therefore one of the technologies that can decarbonise this sector. In addition, these systems can supply not only heat but can also meet the demand for cooling.

However, the sector faces important challenges, some of which are related to regulatory barriers at different levels that affect the implementation of these systems in the cities at the level of self-promotion, for housing groups or at the area level with a district heating system.

In this regard and taking into account the basic European Union regulations on the implementation of renewable energies within the regulatory framework for EU28 countries, the European Commission is committed to achieving the following objectives by the end of the year 2020:

- Reducing at least 20% of greenhouse gas emissions compared to 1990 levels;
- Achieving 20% of the final energy consumption from renewable sources;
- And finally, achieving an improvement in energy efficiency in the construction sector of 20%.

With these objectives for the entire EU28 territory, shallow geothermal energy represents a renewable energy source with wide potential and therefore it should be a key technology in achieving the objectives of the EU's energy policy in the years to come.

Some additional benefits of the use of shallow geothermal technologies are:

- Reducing dependence on fossil fuel imports – which in many cases are subject to the swings of financial markets – and increasing the security of the energy supply;
- Increasing local added value, generating wealth, creating jobs, establishing population and businesses;
- Attracting innovation by creating industrial R&D and technology parks;
- Contributing to the provision of affordable energy without the price volatility that is typical of fossil fuels in international commodity markets.

How shallow geothermal energy works

Shallow geothermal energy is used to describe systems installed at no more than a depth of 500 m to take advantage of the temperature, which is below 100 °C in the case of low enthalpy and below 25 °C in the case of very low enthalpy (Rivas, 2019).

Shallow geothermal energy is usually produced using heat pump technology which is an electrical device that extracts heat from one place and transfers it to another. These devices transfer heat by circulating a substance through evaporation-condensation cycles. A compressor pumps this refrigerant between two coils that exchange heat. In one of them the refrigerant evaporates at low pressure and absorbs the heat from its immediate surroundings. Then, the refrigerant is compressed at high pressure in the other coil where it condenses. At this point, it releases the heat that it absorbed previously. The heat pump cycle is fully reversible, and heat pumps can provide year-round climate control – heating in winter and cooling and dehumidifying in summer. Since the ground and air outside always contain some heat, a heat pump can supply heat even on cold winter days (NRC, 2018).

In a favourable context to the use of shallow geothermal energy, the heat can be extracted directly from the ground or, where appropriate, from the groundwater contained by the aquifers. The depth required to use a heat pump will depend on the heating demand. The need for heating in a single-family home is not the same as what a neighbourhood, a residential area or an industrial estate. This is why the geothermal surface energy can be divided according to the depth and constant temperature of the subsoil in several types that are directly related to the indicated heat output (Krarti *et al.*, 1995):

- Up to 0.5 m depth: The surface of the soil exchanges heat with the atmosphere and is undergoes daily temperature variations.
- Up to around 10 m depth: Seasonal temperature variations are noticeable in the ground. Some authors consider that in the south of Europe from 5 m depth, the temperature is around 15°C with small variations (e.g. Burroughs, 2003). From 10 m deep and depending on the characteristics of the subsoil the temperature of the ground can remain constant throughout the year.
- At a depth of 15 m: The soil is considered to be at constant temperature all year round with a value that, depending on the external climatic conditions, may be slightly higher than the average annual surface temperature. From this depth, the temperature of the subsoil does not depend on seasonal variations in temperature, only on geological and geothermal conditions.
- Below 20 m depth: The temperature increases at a rate of 3 °C per 100 m (average geothermal gradient), being 25–30 °C at 500 m depth in most of the planet.

With all the exposed so far, it can be said that from 15 m depth the temperature of the subsoil will be constant throughout the year, being higher than the atmospheric temperature in winter and much colder in summer (obviously this will depend on the climatic zone where the geothermal installation is located).

Also, taking into account that a heat pump has a better performance the lower the temperature difference between the indoor environment (home) and the environment where heat is sought (subsoil or groundwater), it seems clear that it will be more efficient to get the heat from a medium where the temperature is around 15 °C throughout the year than from an environment where the temperature in winter can be below zero degrees and in summer reach 40 °C (Llopis y Rodrigo, 2014).

To know the exact characteristics and temperature of the subsoil it is necessary to carry out tests, which are often expensive, so for the design of low-power (e.g. single-family residences) installations standardised values of the thermal properties of the land are usually used. These values serve as a guide for a first estimate of the number of geothermal drillings or metres of surface pipe required, although afterwards it will be necessary to check these data.

When/why/where to choose a heat pump

The outside air is the fundamental parameter to determine whether it is possible to use a heat pump as an air conditioning system. The reason is that the interior conditions are fixed by the regulations (in Spain, Regulation of Thermal Installations in Buildings, RITE), while the outside temperature depends on each location. With the heating mode of the heat pump you can know if it is possible to use this type of air conditioning.

The decrease in the outside temperature decreases the heating capacity of the system making it very complicated to install a heat pump in places with temperatures below 0 °C during many winter days. For coastal areas where temperatures are moderate and stable are frequent, good results are

obtained. In practice, it is considered that -5 °C is the operating limit temperature for an air-air pump (Somogyi *et al.*, 2017).

Types of heat pumps (Omer, 2008; Sarbu and Sevarchievici, 2013)

Depending on the fluid (air or water) found in the hot or cold spots of the air conditioning, there are different kinds of heat pumps:

Air-Air

This is very typical in domestic air conditioning since its installation is very simple. Split type units are the most used in homes of 60–120 m^2. They consist of an indoor unit and an external unit with two different operations that take advantage of the phase change of the refrigerant: in summer, they take the heat from the interior and transport it to the outside, while in winter they take heat from the outside air and pump it inside.

Air-Water

The air-water heat pump also uses outside air and still has the outside temperature limitations of air-to-air pumps. It is used in systems with the support of another heating system or domestic hot water. Water with this system is heated to between 30 °C and 60 °C. This system is suitable in those places where, due to its temperature range, heating is required in winter and cooling in summer. When used to generate hot water its annual yield is optimal.

Water-water

The system is similar to the previous one but the heat transfer is in a water circuit. The disadvantages regarding the proximity of surface water sources are similar to those of the previous system. Its combined use with renewable energies, such as solar thermal energy, may be adequate for this system, although it is quite complex.

Earth-Water

The heat and cold of the air conditioning system is achieved with the transfer of heat from and to the ground. A large area is needed to place the buried installation, about four times the surface of the building to be heated. The study of the shallow soil in this type of systems is fundamental to correctly dimension this type of heat pump. If land area is limited, vertical geothermal energy is another option. To calculate the type and depth of boreholes it is necessary to know the geology of the subsoil and a series of parameters related to the geothermal gradient.

Shallow geothermal energy in the EU28

If we take into account the territory occupied by the current members of the European Union, in terms of the number of facilities, installed capacity and energy produced, shallow geothermal is the largest and most widespread geothermal energy sector in Europe; the power generation facilities (medium and high enthalpy) are restricted to a few countries with certain geological conditions, such as Italy, France or Iceland (outside of the EU28 but in the EEA), for example.

In this context, the European countries with the most quantity in number of installations of shallow geothermal heat capture systems are Sweden, Germany, France and Switzerland (not included in the EU28). These four countries account for 64% of all installed capacity in Europe (ReGeoCities, 2017).

EU legislation on shallow geothermal energy

The basic legislation of the European Union on energy was based for many years exclusively on the European Commission Authority for the internal market and the environment. However, with the inclusion of a modification in the Lisbon Treaty of 2009, energy has become an area of shared competence between the institutions of the Union and the Member States.

In fact, Article 194 of the Treaty of the Union states that in the context of the establishment and functioning of the internal market and regarding the need to preserve and improve the environment, the European Union's energy policy, in the spirit of solidarity between Member States, should try to:

a. ensure the functioning of the energy market;
b. strengthen the security of energy supply in the European Union;
c. promote efficiency, energy saving and the development of new and renewable forms of energy.

This provision, therefore, legitimises the European Union to legislate on various issues that directly or indirectly affect the geothermal sector of low and very low temperature.

Therefore, we can summarise the fundamental legislation for geothermal energy in the EU28 in the following:

- Directive 2009/28/EC on the promotion of the use of energy from renewable sources;
- Consolidated Directive 2010/31/EU on the energy performance of buildings;
- Directive 2012/27/EU on energy efficiency;
- Consolidated Directive 2009/125/EC establishing a framework for the setting of ecodesign requirements for energy-related products;
- Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU on the indication through labelling and standardised product information on energy consumption and other resources in energy-related products.

Based on this legislative background, the European Commission set a timetable for the implementation of EU28 legislation relevant to shallow geothermal energy with the following milestones:

- By July 2012: Member States had to transpose the 2010 version of the Directive that replaced the previous version of 2002;
- 2013: The European Commission published guides on the calculation of renewable energy of heat pumps;
- 2014: Member States had to renew an average of 3% of public buildings each year in relation to energy efficiency and substitution of fossil fuels for clean energies;
- 2015: Member States should establish minimum levels of renewable energy in the energy consumption of buildings;
- 2017: Member States had to incorporate to the own legislation the 2017 Regulation that replaced the previous Directive 2010/30;
- December 31, 2018: All new public buildings must be constructions where renewable energy prevails against fossil fuels of any kind
- December 31, 2020: All new private buildings must be constructions where renewable energy prevails against fossil fuels of any kind.

Table 1: Energy objectives of renewable energies in some of the EU Member States, 2010 and 2020 (modified from ReGeoCities).

Country	Final energy consumption in 2010 (ktoe)	Part of renewables in air conditioning in 2010 (ktoe)	Part in percentage (%)	Predicted final energy consumption in 2020 (ktoe)	Predicted share of renewables in air conditioning in 2020 (ktoe)	Predicted share in percentage (%)
Austria	12,007	3657	30.5	12,802	4179	32.6
Belgium	21,804	766	3.5	21,804	2588	11.9
Czech Republic	17,805	1810	10.2	18,680	2672	14.3
Denmark	8,042	2480	30.8	7,653	3042	39.7
Finland	14,010	5210	37.2	15,300	7270	47.5
France	67,159	11124	16.6	60,000	19732	32.9
Germany	111,597	10031	9.0	93,139	14431	15.5
Greece	8,644	1269	14.7	9,674	1908	19.7
Hungary	10,347	949	9.2	9,719	1863	19.2
Ireland	5,160	220	4.3	4,931	591	12.0
Italy	58,976	3851	6.5	61,185	10456	17.1
Netherlands	24,612	906	3.7	24,989	2179	8.7
Poland	32,400	3980	12.3	34,700	5921	17.1
Portugal	7,286	2240	30.7	8,371	2507	29.9
Romania	15,788	2819	17.9	18,316	4038	22.0
Spain	33,340	3764	11.3	29,849	5645	18.9
Sweden	14,488	8237	56.9	16,964	10543	62.1
United Kingdom	60,000	518	0.9	51,500	6199	12.0

Management of shallow geothermal resources and protection of the environment

The development of shallow geothermal systems of low or very low temperature can be affected by administrative measures at different levels for the promotion of renewable energy and energy efficiency, as well as by the European and State regulation aimed at protecting and improving the environment.

For example, Directive 2000/60/EC, which establishes a framework for community action in water policy and specifically for groundwater located in aquifers, requires Member States to implement measures to prevent water deterioration and prevent or limit its contamination.

Groundwater is considered quantitatively (in volume) much more significant than surface water. Therefore, the prevention of possible contamination due to any cause, its monitoring and, where appropriate, its restoration are much more complicated due to its direct inaccessibility. That is why this Directive gives priority to any other condition and establishes the prohibition of direct water discharge to groundwater.

Due to this, the application of water legislation to shallow geothermal energy will depend on the system for capturing heat from soil. It is important to highlight that – following the tendency to share responsibility between the European Union and national governments – Article 11 of Directive 2000/60/EC gives the Member States the possibility of authorising the re-injection of the water used for shallow geothermal purposes into the same aquifer in the case that it does not compromise the environmental objectives.

This Directive is complemented by Directive 2006/118/EC on the protection of groundwater against its pollution and deterioration. This Directive establishes specific measures to prevent pollution and to limit the introduction of pollutants. It also introduces criteria for the good chemical status of groundwater and criteria for the identification of points of change.

However, in other fields that also affect shallow geothermal energy, the EU only defines a general framework or one that has a minor impact. This means that the largest source of regulation is national and that, finally, it can vary and in fact does vary from one country to another. This is the case with, for example, soil protection.

Likewise, it remains a national competence to determine whether a shallow geothermal drilling project should be subject to a study in accordance with Directive 2011/92/EC on the effects of certain public and private projects on the environment. In the case of Spain, for example, it is the mining law that regulates the implementation of drilling, establishing responsibilities and competent technicians.

Finally, it is important to emphasise that, while the evolution of legislation in the European Union may increase the opportunities to implement shallow geothermal systems in Europe, the development of these technologies will depend on national and, in some cases, regional or local legislation.

National objectives regarding the use of shallow geothermal energy

Renewable Energy Directive (2009/28/EC) required the Member States to send renewable energy action plans before June 30, 2010. These plans were intended to provide detailed roadmaps of how each EU28 State hoped to achieve the goals committed for 2020 in renewable energies and the energy mix that they hoped to use to supply the population, agriculture and industry. ***Table 1*** shows the objectives of selected Member States for 2010 and 2020.

We can see how the European Union has set objectives to ensure that from 2020 all new buildings are energy efficient, while recognizing the differences in the types of buildings built and the climate of different

countries and regions of Europe.

This is why Directive 2010/31/EU requires that Member States must ensure that all new buildings occupied and in possession of local authorities after 31 December 2018 will be almost zero energy , by 31 December 2020 all new buildings are also in this category Member States should also develop national plans to increase the number of buildings with low energy consumption characteristics and develop policies that take measures for the establishment of stimulus objectives for the transformation of buildings to low-consumption energy buildings. Such buildings are defined in Article 2 of the recast Directive as buildings with high energy efficiency: 'The demand for energy, close to zero or very small, should be covered mainly by renewable sources, including renewable energy produced on or near the site.'

Unfortunately, the main building codes and incentives for the construction or renovation of buildings towards those with low energy consumption rarely mention shallow geothermal systems. However, the option of including them under the umbrella of other renewable systems is generally accepted, since these shallow geothermal systems fit into national legislation on renewable energies at all levels. The methods of calculating energy savings must be carried out with methods approved by the European Union.

In some countries, such as France, Spain, Italy and the Netherlands, the regulations of air conditioning and building codes do not clearly indicate that shallow geothermal systems should be considered as a possible solution for reducing energy consumption in buildings (Haehnlein *et al.*, 2010):

- In France, the 2012 regulation for new constructions (RT2012) gives maximum energy consumption values for heating, domestic hot water, refrigeration, lighting and auxiliaries.
- In Spain, in the Technical Building Code (CTE) there are requirements related to renewable energies exclusively for the production of water (60% of hot water must come from renewable sources), which in most cases is achieved by means of thermal solar panels regulated by regulations of regional or local scope.
- In Italy, the Legislative Decree of 3 March 2011 (n.28) introduces quantitative objectives for the integration of heating, ventilation and air conditioning systems with renewable energy in regard to new buildings and structural rehabilitation of buildings. Shallow geothermal systems are not specifically considered.
- In the Netherlands, shallow geothermal energy is not directly integrated into the legislation for air conditioning of buildings but is indirectly affected by the Construction Regulations.

Conclusions

We can conclude that although European legislation includes and encourages the use of shallow geothermal energy as an important means of reducing greenhouse gases in the generation of hot water and air conditioning of housing, agriculture and industry, the legal frameworks of the different EU28 members are very diverse in what concerns the obligation of the inclusion of surface geothermal energy among the different renewable energy systems that can be used for these tasks. Likewise, different countries, depending on the transposition mode of the European Directives on energy, water and environment, enact legislation that regulates to a greater or lesser extent the use of different shallow geothermal capture systems and how to interact with the masses of groundwater.

This overview also indicates that the regulatory framework can be a barrier to the development of shallow geothermal systems. The lack of regulation, complex procedures, delays in administrative approvals, costly procedures, distribution of competences in a complex manner between different authorities (national and local) and heterogeneous procedures depending on the region could be usually the most common obstacles to national development and regional shallow geothermal systems in the air conditioning of buildings.

Shallow geothermal energy of low and very low temperature is a type of energy directly related to geology, relatively easy to extract, not requiring transport, with a cost perhaps somewhat more expensive in its installation than a diesel installation but with a higher efficiency and return on investment to families and also to industry (the average cost of a geothermal installation in a single-family home is between 20,000–40,000 euros depending on the number of wells to be made and the type of terrain, as well as the power of the heat pump to be used (Clickrenovables.com, 2018). It can be supplied according to needs and without uncertainty in the prices, since it is not subject to speculative ups and downs produced by financial markets. It is a clean and inexhaustible energy that constitutes a real energy transition from fossil fuels and that unfortunately has not been sufficiently promoted and encouraged by the national and regional authorities in their legislative capacity.

This is why the shallow geothermal energy should have a regulatory framework that goes hand in hand with the advancement of science and technology in shallow geothermal heat capture systems to encourage their use in newly built and refurbished homes and buildings, in agriculture and in industry.

Finally, broader geological survey of the entire territory of the EU28 would lead to better knowledge of the shallow soil for the most efficient systems of extraction of underground heat for hot water and air conditioning, thus reducing the effects of climate change and helping to ensure the future of our planet.

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